

CLAIMS

1. A light detecting element formed in a semiconductor device, the light detecting element comprising:

a photosensitive unit for receiving light irradiated from a light source,
5 said photosensitive unit generating electrons and holes each of which the number varies with quantity of light received at the photosensitive unit;

a carrier separation unit with a separation control electrode, said carrier separation unit separating the electrons and holes generated at said photosensitive unit into object carriers and non-object carriers according to
10 control of electric potential applied to the separation control electrode, said object carriers being one of the electrons and holes, said non-object carriers being another of the electrons and holes;

a recombination unit with a recombination control electrode, said recombination unit stimulating recombination between the object carriers
15 generated at said photosensitive unit in a light period and the non-object carriers generated at said photosensitive unit in a extinction period according to control of electric potential applied to the recombination control electrode, said light period being a period of time that said light source is operated, said extinction period being a period of time that said source is
20 extinguished; and

an output unit for picking out the object carriers remained after the recombination at said recombination unit.

2. The light detecting element of claim 1, wherein said carrier
25 separation unit adjusts so that the number of the object carriers is larger

than the number of the non-object carriers, said object carriers being generated in the light period to be given to the recombination at said recombination unit, said non-object carriers being generated in the extinction period to be given to the recombination at said recombination unit.

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3. The light detecting element of claim 1, further comprising:

an object carrier holding unit for gathering the object carriers generated at said photosensitive unit to hold the object carriers until the recombination; and

10 a non-object carrier holding unit for gathering the non-object carriers generated at said photosensitive unit to hold the non-object carriers until the recombination;

wherein said recombination unit stimulates the recombination between the object carriers held at said object carrier holding unit and the
15 non-object carriers held at said non-object carrier holding unit.

4. The light detecting element of claim 3, wherein said carrier separation unit further comprises a switch unit for disposing of the object carriers held at said object carrier holding unit.

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5. The light detecting element of claim 1, wherein said output unit has an integration function for integrating the object carriers remained after the recombination at said recombination unit.

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6. The light detecting element of claim 3, comprising:

an element formation layer of a first conductive type, said element formation layer being formed on a main surface of a semiconductor substrate;

5 a well region of a second conductive type, said well region being formed at a main surface side within said element formation layer;

a surface electrode which is formed on the main surface of said element formation layer to face at least said well region through an insulating layer, said surface electrode having translucency;

10 a first holding region of the second conductive type, said first holding region being formed within said well region and at the main surface side of said element formation layer as said object carrier holding unit;

a second holding region of the first conductive type; said second holding region being formed within said first holding region and at the main surface side of said element formation layer as said non-object carrier holding unit; and

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a common control electrode as said separation control electrode and said recombination control electrode, said common control electrode being located to face said second holding region through said insulating layer, said common control electrode having translucency;

20 wherein: said photosensitive unit includes said element formation layer which generates the electrons and holes; and

said recombination unit includes at least one of said first holding region and said second holding region.

25 7. The light detecting element of claim 6, further comprising:

a drain region of the second conductive type, said drain region being provided for disposing of the object carriers from said object carrier holding unit, said drain region being formed at the main surface side within said element formation layer and in proximity to said well region; and

5 a drain electrode which is coupled to said drain region by ohmic coupling, said drain electrode being applied with electric potential so as to dispose of the object carriers from said first holding region to said drain region.

10 8. The light detecting element of claim 3, comprising:

an element formation layer of a first conductive type, said element formation layer being formed on a main surface of a semiconductor substrate;

15 a well region of a second conductive type, said well region being formed at a main surface side within said element formation layer as said object carrier holding unit;

a surface electrode which is formed on the main surface of said element formation layer to face at least said well region through an insulating layer, said surface electrode having translucency;

20 a holding region of the first conductive type, said holding region being formed within said well region and at the main surface side of said element formation layer as said non-object carrier holding unit; and

a common control electrode as said separation control electrode and said recombination control electrode, said common control electrode being
25 located to face a part of said holding region through said insulating layer,

said common control electrode having translucency;

wherein: said photosensitive unit includes said element formation layer which generates the electrons and holes; and

said recombination unit includes at least one of inside and outside of
5 said holding region within said well region.

9. The light detecting element of claim 3, comprising:

an element formation layer of a second conductive type, said element formation layer being formed on a main surface of a semiconductor substrate
10 of the second conductive type through an intermediate layer of a first conductive type;

a well region of the second conductive type, said well region being formed at a main surface side within said element formation layer as said object carrier holding unit;

15 a surface electrode which is formed on the main surface of said element formation layer to face at least said well region through an insulating layer, said surface electrode having translucency;

a holding region of the first conductive type, said holding region being formed within said well region and at the main surface side of said
20 element formation layer as said non-object carrier holding unit; and

a common control electrode as said separation control electrode and said recombination control electrode, said common control electrode being located to face a part of said holding region through said insulating layer, said common control electrode having translucency;

25 wherein: said photosensitive unit includes said element formation

layer which generates the electrons and holes; and

said recombination unit includes at least one of inside and outside of said holding region within said well region.

5 10. The light detecting element of claim 6, further comprising:

a buried layer for increasing potential barrier between said well region and said element formation layer, said buried layer being formed at the bottom of said well region;

 wherein said well region within said element formation layer is
10 formed so as to be apart from said substrate.

11. The light detecting element of claim 8, further comprising:

a buried layer for increasing potential barrier between said well region and said element formation layer, said buried layer being formed at
15 the bottom of said well region;

 wherein said well region within said element formation layer is formed so as to be apart from said substrate.

12. The light detecting element of claim 9, further comprising:

20 a buried layer for increasing potential barrier between said well region and said element formation layer, said buried layer being formed at the bottom of said well region;

 wherein said well region within said element formation layer is formed so as to be apart from said substrate.

13. A control method of the light detecting element of claim 3, the control method comprising, controlling the electric potential applied to said separation control electrode so as to:

gather the object carriers at said object carrier holding unit while
5 disposing of the non-object carriers in the light period; and

gather the non-object carriers at said non-object carrier holding unit while disposing of the object carriers in the extinction period.

14. A control method of the light detecting element of claim 6, the
10 control method comprising:

applying to said common control electrode with electric potential for holding the object carriers and the non-object carriers at said object carrier holding unit and said non-object carrier holding unit respectively; and then

changing the electric potential applied to said common control
15 electrode so that at least one of the object carriers held at said object carrier holding unit and the non-object carriers held at said non-object carrier holding unit moves to be given to the recombination between the object carriers and the non-object carriers.

20 15. A control method of the light detecting element of claim 8, the control method comprising:

applying to said common control electrode with electric potential for holding the object carriers and the non-object carriers at said object carrier holding unit and said non-object carrier holding unit respectively; and then

25 changing the electric potential applied to said common control

electrode so that at least one of the object carriers held at said object carrier holding unit and the non-object carriers held at said non-object carrier holding unit moves to be given to the recombination between the object carriers and the non-object carriers.

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16. A control method of the light detecting element of claim 9, the control method comprising:

applying to said common control electrode with electric potential for holding the object carriers and the non-object carriers at said object carrier holding unit and said non-object carrier holding unit respectively; and then
10 changing the electric potential applied to said common control electrode so that at least one of the object carriers held at said object carrier holding unit and the non-object carriers held at said non-object carrier holding unit moves to be given to the recombination between the object
15 carriers and the non-object carriers.

17. A control method of the light detecting element of claim 8, the control method comprising:

applying to said common control electrode with electric potential for
20 holding the object carriers and the non-object carriers at said object carrier holding unit and said non-object carrier holding unit respectively; and then
changing the electric potential applied to said common control electrode at plural times so that the recombination is stimulated between the object carriers and the non-object carriers by:

25 making the object carriers move back and forth between inside and

outside of said holding region within said well region; and also

making the non-object carriers move back and forth between parts facing and not facing said common control electrode within said holding region.

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18. A control method of the light detecting element of claim 9, the control method comprising:

applying to said common control electrode with electric potential for holding the object carriers and the non-object carriers at said object carrier holding unit and said non-object carrier holding unit respectively; and then

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changing the electric potential applied to said common control electrode at plural times so that the recombination is stimulated between the object carriers and the non-object carriers by:

making the object carriers move back and forth between inside and outside of said holding region within said well region; and also

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making the non-object carriers move back and forth between parts facing and not facing said common control electrode within said holding region.

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19. A control method of the light detecting element of claim 8, the control method comprising:

controlling the electric potential applied to each of said surface electrode, said common control electrode and said substrate so as to:

gather the non-object carriers at said holding region while disposing of the object carriers in the extinction period; and also

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gather the object carriers at said holding region while disposing of the non-object carriers in the light period.

20. A control method of the light detecting element of claim 9, the
5 control method comprising:

controlling the electric potential applied to each of said surface electrode, said common control electrode and said substrate so as to:

gather the non-object carriers at said holding region while disposing of the object carriers in the extinction period; and also

10 gather the object carriers at said holding region while disposing of the non-object carriers in the light period.

21. A control method of the light detecting element of claim 14, the control method comprising:

15 reversing polarity between each electric potential applied to said surface electrode and said common control electrode and the electric potential applied to said substrate, in a state for gathering the object carriers during the light period and a state for gathering the non-object carriers during the extinction period;

20 reversing polarity of the electric potential applied to said common control electrode at plural times in a state for stimulating the recombination between the object carriers and the non-object carriers in at least one of the light period and the extinction period; and

picking out the object carriers remained at said well region after the
25 recombination.